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FINGERPRINT IMAGE ENHANCEMENT TECHNIQUE AND ITS QUALITATIVE ANALYSIS

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ABSTRACT

The research paper have a new design technique with the application of diffrent kind of filters for fingerprint image enhancement implemented and coded. The result obtained in design is discussed with analysis for each stage of filter.For qualitative analysis two quality measure PSNR and MSE is introduced.With the help of this quality measure and result obatined is further analysed with mathematical statistics, line and bar diagram. Some of result statistics found very good in design and some stage it has got limitation.Limitation are also brought for discussion and some future course of action on design is kept for future exploration.

KEYWORDS: Fingerprint Image, Image Enhancement, Frequency Domain, Image Quality, PSNR and MSE, Mathematical Statistics and Analysis

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Original Article

INTRODUCTION

Fingerprint image is complex structure of ridge and valley formed on the finger epidermis. It is unique, distinctive and immutative pattern developed during embryonic devlopment stage [1].It has unique biological and biometric formation properties, it is reason that it has been used for personal identification, criminals identification by law enforcement agengcies in the worlds since centuries. It has found application in restricted areas e.g. airports control, nuclear applications control room and some other critical area of applications.Any AFIS for their operation heavily rely on minutiae matching. Minutiae [1] known as local discontinuities has two form : ridge ending and bifurcation. Short ridges and enclosures are other form of minutiae discontinuities. In a good quality fingerprint image number of minutiae ranges between 40 to 150. Ideally a good quality image receive ridges and valleys and they are separated narrowly and they have flow in parallelism order but in constant direction [2].But practically acquired image found by digital acquisition devices too are not well defined and good quality because of mingling of noise like creases, smudges and holes etc and it does corruption of the ridge structure clarity. The noise can occure by diffrent reason : e.g. pelt (skin) condition variation, impression collection ways and non-uniform contact of finger while acquisition is taking place. This deterioration creates pseudo-minutiae and results matching error [3]. For reliable matching and automatic identification without any error, these pseudo-minutiae must be eliminated by the use of well designed and effective image enhancement method.

Any image acquired can be enhanced either on grey scale or if it is in binary form. Spatial domain enhancenment is done on grey scale because spatial enhancement does intensity transformation directly on pixels.Binary image enhancement create pseudo minutiae, so it is not much used. In frequency domain complete

image is convolved with filter function and then again inverse Fourier transformed to get back enhanced image. K millard et al [4] has applied 16 set of directional Fourier filter being tuned in between 0 to 180^0 and thus they got 16 set of enhanced image. M. Mizoguchi et al [3] used filter applying Fourier transform. Raicevic et al [5] used adaptive frequency filter and Sanchez et al [6] has applied FFT and Gabor filter for enhancement and recognition.

The paper is further organized as follows : First part is brief introduction about fingerprint image and brief history of fingerprint image enhancement method proposed by reknowned researcher. Second part describes algorithm applied in fingerprint image enhancement. Third part deals about how complete design is implemented with use of diffrent type of filters. Furthure fourth section discusses about results obatined at different filters stage. Fifth section have brief idea about quality measure applied in design, followed by result obtained with detailed analysis and quick look bar and line diagram sketch.Conclusion, Limitation and Future course of action are followed on further subsection. In last acknowledgement and refrences is briefly put for perusal.

Finger Print Enhancement-Algorithm

In fingerprint image enhancement following algorithm applied.This is modular architecture that includes several step and they are given below (refer Figure1)

- **Image Acquisition:** Image acquisition is first step and image is acquired by some means of acquisition device.
- **Image Normalization**: In second step image is normalized for pre-specified mean and variance.
- **Edge Filtering:** Edge filte is applied to change the intensity of edges and corner of fingerprint image.
- **Binarization and Thinning**: Binarization operation generates binary image with grey scale image. Thinning operation is termed as morphological process and it erode till foreground pixels width remain one pixel width size.
- **Orientation Extraction:** Orientation estimation and extraction is carried out on normalized image.
- **Ridge Frequency Computation:** Ridge frequency is computed from the normalized fingerprint image.
- **Gabor Filtering**: 8 no's Gabor kernel are applied on the fingerprint to enhance ridge frequency and orientation of image.
- **Image Intensity Calculation:** Image intensity of enhanced image is calculated to measure intensity of filtered image.
- **Frequency and Directional Filter:** Frequency and directional filter is designed to enhance frequency and direction of enhanced image.

Implementation Process

Fingerprint image enhancement as described in above algorithm is implemented with block diagram shown in Figure1. Finger print image acquired either by means of acquisition device or from old data base is made to input. The image is normalized to pre-fixed mean and pre-fixed variance for sensor noise removal, standardize intensity values by adjusting grey level of ridge and valley structures. Normalized image is edge filtered using Z.C.Shi grey-based algorithm [7] to enhance the edges and segment the image. Image is segmented with selecting suitable variance threshold to

differentiate foreground and background regions. With edge filter corners, lines, curves are extracted. Edge filtered image is binarized which converts grey scale image into binary image using adaptive thresholding [3]. Thinning is morphological operation and it continue eroding operation until foreground pixels are one pixel wide and preserves the connectivity of the ridge structure [3]. This image is fed to Gabor filter bank tuned to different orientation. Gabor filter [1, 2, 6] detect and correct edges, remove noise, preserve ridge and valley structure in fingerprint image.

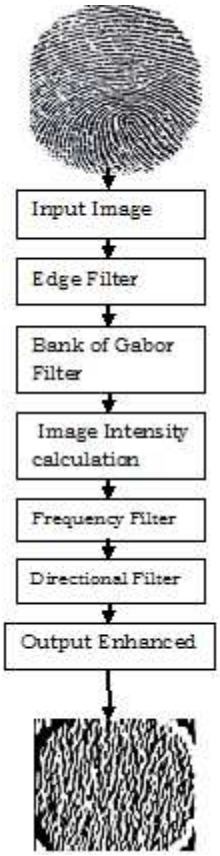

Figure 1: Finger Print Enhancement Block Diagram

Histogram processing and equalization which in turns assist in calculating image intensity as well as perform like filter. The intense image is fed to frequency filter. Image is first Fourier transformed, convolved with filter and Inverse Fourier transformed to get back enhanced image. Frequency filter suppresses low frequency unevenness and noise produced by high frequeny. We have a need to cover entire region of fingerprint image, so a directional filter is designed which enhances ridge direction. In last two qualities measure PSNR and MSE is introduced to evaluate the image quality to compare with other enhancement methods. Typical values for the PSNR lies between 40 to 60 dB for 8 bit data length but dB value obtained more than this is far better result. Lower the value of MSE higher the quality of image.

Enhanced Finger Print Results

In the designed method (refer Figure1) first image is made input and it is normalised to a constant mean and variance.output of normalisation step is shown in Figure2(b).Normalised image is fed to edge filter which does enhancement of edges and corners of cropped area 200x200 pixels as shown in fig,2(c).Edge filtered image is fed to

Figure 2(a): Input Image

Figure 2(b): Normalised Image

Figure 2(c): Edge Filtered Image

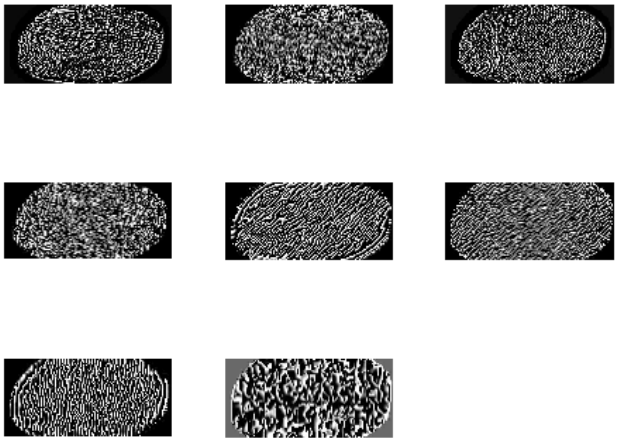

Figure 2(d): Gabor Filtered Image

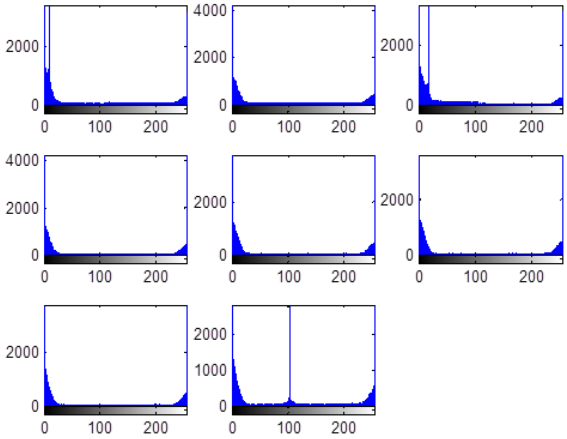

Figure 2(e): Histogramme Image

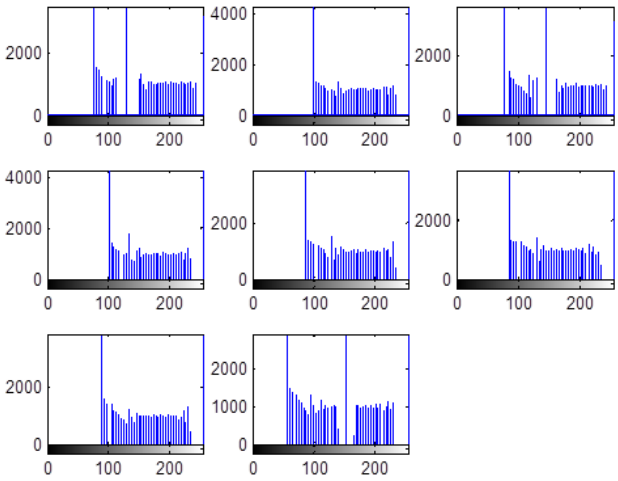

Figure 2(f): Histogramme Equalised Image

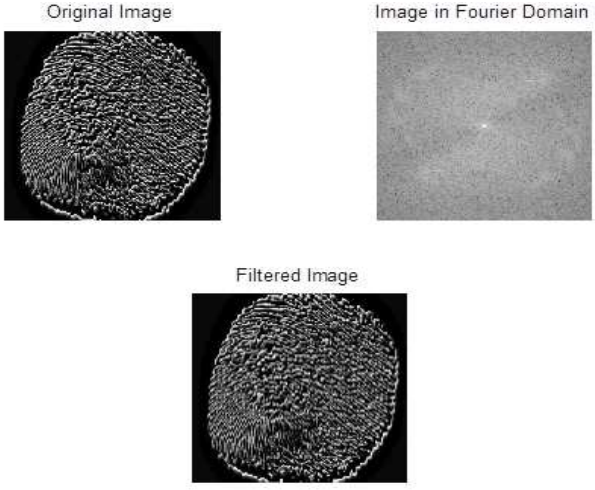

Figure 2(g): Frequency Filtered Image (1.8)

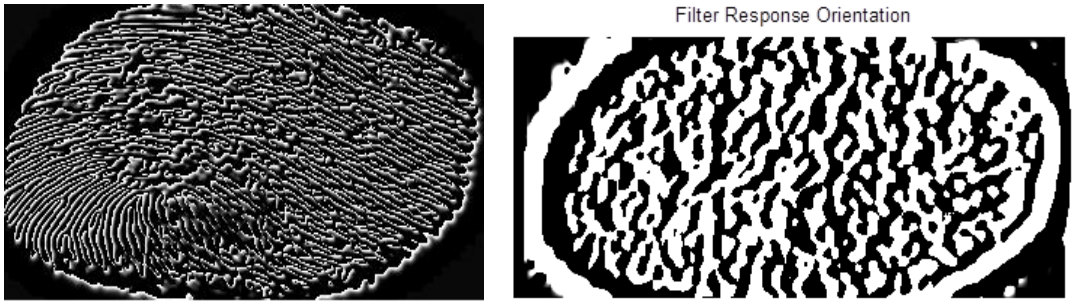

Figure 2(h): Frequency Filtered Image (1.8)

Gaber filter bank tuned to different oreintation and in out put response, we get eight enhanced image as shown in Figure2(d).Gabor Enhance image is further intentensity enhanced by Histrgram processing and Equalisation method and output found is shown in Figure 2(e) and Figure 2(f). The Intense image thus obtained by intensity enhancement process is fed to frequency filter and directional filter. The ouput response of Frequency and Direction filter is presented in figure 2(g) and figure 2(h) respectively.

Qualtative Measrue Coded

Filter design shown in Figure1 has provided enhanced image as obtained in diffrent stages and shown in Figure2. For qualitative analysis, two quality measure PSNR and MSE is introduced and coded to evaluate the performance.

P.S.N.R

P.S.N.R. (Peak signal-to-noise ratio) [8] is ratio of a signal having maximum power to deteriorating noise power. It has impact on image representation. PSNR can be defined in terms of logarithmic decibel scale:

$$\text{PSNR} = 10 \log_{10} \frac{(\text{Max}^2_i)}{(\text{MSE})} = 20 \log_{10} \frac{(\text{Max}_i)}{(\sqrt{\text{MSE}})}$$

$$\text{PSNR} = [\{20 \log_{10} (\text{Max}_i)\} - \{10 \log_{10} (\text{MSE})\}] \quad (1)$$

Whereas Max_i is that image which has maximum extent value of pixel. Its maximum value is 255, when pixels are represented in 8bps. When its samples are represented in linear PCM keeping b bits per sample, Then Max_i can be calculated $=2^b-1$.

In Fingerprint image gesture (signal) is the actual finger image and detonation (noise) is the imperfection induced during enhancement process. If we get high value of PSNR, It is indication of very good quality image restitution of image. Typical value of PSNR in noisy image lies in range of 40 to 60 dB if 8 bits length selected but better than this value is always appreciated and useful.

M. S. E.

M.S.E. (mean square error) is quantitative estimation of difference in implied estimate value and the real (true) quality being certified. MSE is also termed risk function of squared error which has correspondence with expected value. It is second moment of error and includes variance and bias of the estimate. Considering rattling (noise free) x×y grey scale

image M and its shrilly (noisy) image N, MSE can be expressed as: [8]

$$MSE = \frac{1}{x*y} \sum_{i=0}^{x-1} \sum_{j=0}^{y-1} [M(i,j)-N(i,j)]^2 \quad (2)$$

Here values for fingerprint image quality loss considered will be 20 dB to 25 dB. Lower the value of MSE higher the quality of image.

PSNR AND MSE AT EDGE FILTER

PSNR and MSE result found at the output of Edge filter is tabulated in Table1. Result is plotted with bar diagram and line diagram as shown in Figure3. (a) and 3(b). With the table it is very much clear that edge filter has PSNR in

Table 1:PSNR and MSE of Edge Filter

Image No	PSNR	MSE
Image1	49.3266	0.7593
Image2	48.3003	0.9617
Image3	48.3851	0.9431
Image4	49.0534	0.8086
Image5	49.3217	0.7602
Image6	48.678	0.8816

the range of 47-50 dB which signifies good result. In similar way MSE also have values less than one, indicate good results.

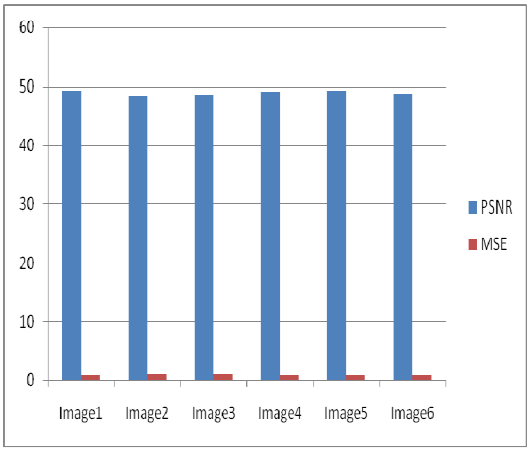

Figure 3(a): Edge Filtered Output PSNR and MSE (Bar Diagram)

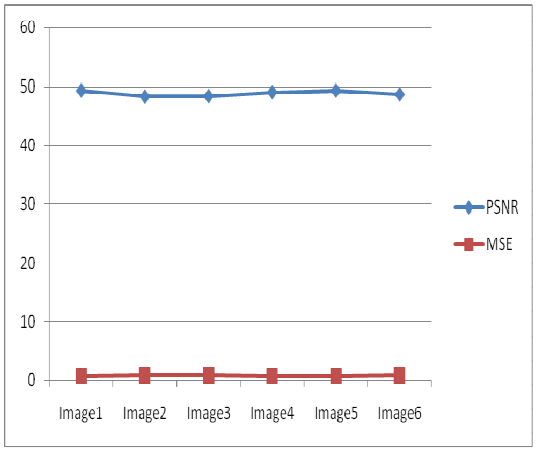

Figure 3(b): Edge Filtered Output PSNR and MSE (Line Diagram)

PSNR AND MSE AT GABOR FILTER

PSNR and MSE measurement carried out at each Gabor kernel for all images. In designed method 8 no's of Gabor kernel are applied thus providing 8 output image, so we too get 8 PSNR and MSE values for each filter as tabulated below. Sum, Average, Variance and Standard deviation is also calculated for measured value of PSNR and MSE. Sum value of PSNR for all 8 images observed in Table.2 signify good value in the range of 63-69 dB whereas Standard deviation and Variance values measured for each filter ranges in between 0.9 to 1.4 signifying good results. MSE values tabulated in Table.3 are large values as we have applied 8 no's Gabor filter for one image at different orientation. Though

Gabor filter have both frequency and orientation-selective properties, still MSE values measured is of poor quality. PSNR values measured are plotted in bar diagram and with line diagram in Figure4 (a) and Figure4. (b) respectively.

Table 2:PSNR of Gabor Filter

Image/Gabor	Image1	Image2	Image3	Image4	Image5	Image6
GF1	8.6976	8.2524	9.1809	7.9828	8.323	9.1366
GF2	8.6976	8.6144	9.2719	8.3206	8.4321	9.0801
GF3	9.193	8.5995	9.3911	8.7629	8.5767	9.6065
GF4	8.8019	8.8099	9.3829	8.5988	8.4185	9.1823
GF5	6.4155	6.4104	6.8811	6.3324	6.3811	6.6742
GF6	8.5738	8.6312	8.9767	8.5793	8.5953	8.6934
GF7	6.6502	6.6357	7.183	6.561	6.5653	6.5632
GF8	8.1501	8.386	8.0423	8.414	8.4393	8.2995
Sum	65.1797	64.3395	68.3099	63.5518	63.7313	67.2358
Mean	8.147463	8.042438	8.538738	7.943975	7.966413	8.404475
St. Dev	1.038543	0.954514	1.029083	0.954474	0.927077	1.166251
Variance	1.078571	0.911097	1.059011	0.91102	0.859472	1.360142

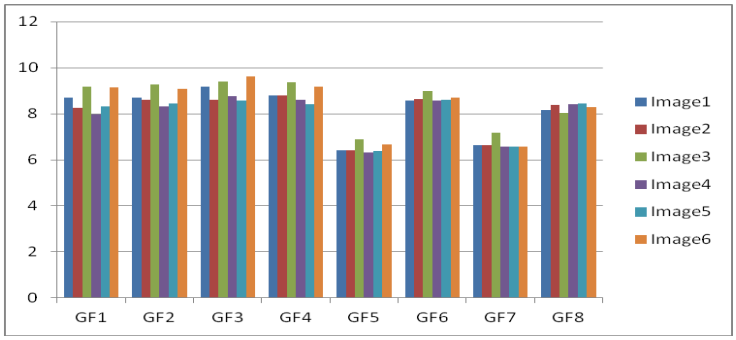

Figure 4(a): Gabor Filter Output PSNR (Bar Digram)

Average, Variance and Standard deviation values calculated and tabulated in Table2 are plotted by line diagram as shown in Figure4 (c).MSE values tabulated in Table 3 are plotted with line diagram as shown in Figure (d)

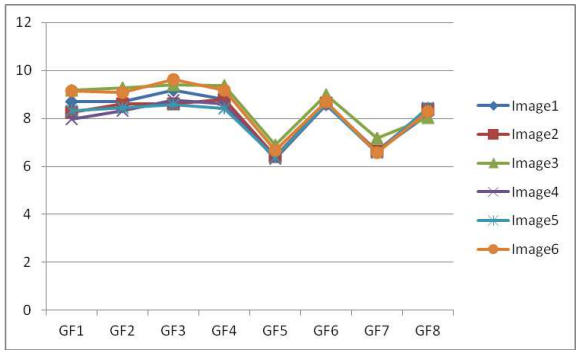

Figure.4 (b): Gabor Filtered Output PSNR (Line Diagram)

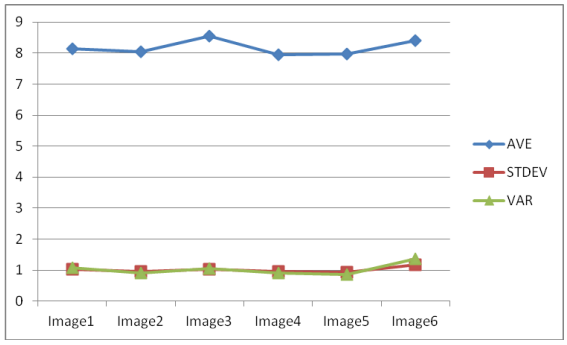

Figure 4 (c):Gabor Filtered Output Average Standard Deviation and Variance

Table 3:.MSE of Gabor Filter

Image Gabor	Image1	Image2	Image3	Image4	Image5	Image6
GF1	8776.4	9723.8	7852.1	10347	9573.7	7932.6
GF2	9175.7	8946.3	7691	9572.4	9329.7	8036.6
GF3	7830.4	8976.9	7481.2	9026.3	8645.5	7119.1
GF4	8568.2	8552.5	7495.4	8978.4	9359.1	7849.6

Table 3: Contd.,						
GF5	8568.2	14861	13334	15130	14944	13985
GF6	9030.2	8911.8	8730.9	9018.9	8985.1	8785
GF7	14062	14110	12439	14354	14340	14347
GF8	9955.2	9429.4	10206	9368.7	9314.3	9619
Average	9495.788	10438.96	9403.7	10724.46	10561.43	9709.238
St. Dev	1941.739	2530.337	2343.229	2527.889	2539.23	2847.921

Mean-Square-Error (MSE) value observed is more because of application of many Gabor filter with different orientation. This value can be optimized by selecting single filter with suitable orientation. Average value and Standard value calculated in table3 do not signify good result values. This of course can be one limitation of the designed method and future research work can be advised on the limitation.

CONCLUSIONS

In this paper a fingerprint enhancement technique with said above algorithms and with the use of diffrent filter is designed and coded.Result of each filter stage by stage is also obtained.To make qualitative analysis two quality measure PSNR and MSE is introduced and result is tabulated in table shown above for Edge and Gabor filter.The results obtained in tables are anaysed by applying mathematical calculation e.g.mean,sum variance and standard deviation. Line diagram and bar diagram is also ploted to have quick look of results.With qualitative analysis, it is found that even Gabor filter output have overall good PSNR result but individual Gabor kernel have no good figure of PSNR and MSE values.It may be a reason because all kernel are tuned to diffrent orientation.Similarly MSE result was also not good for Gabor Filter.

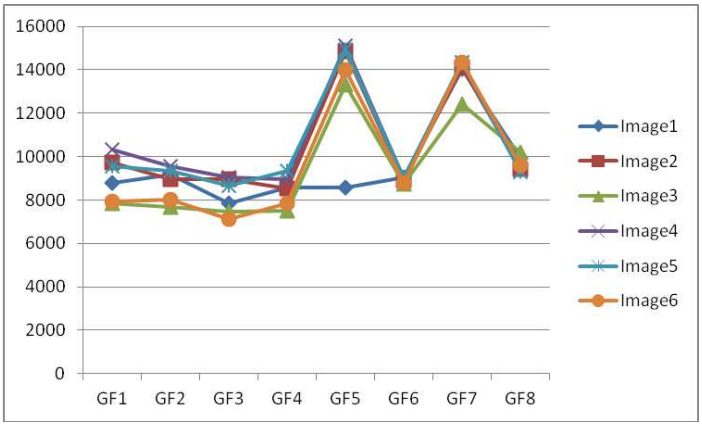

Figure 4(d): Gabor Filtered Output MSE Plot

Limitation

The performance of the Gabor filter in design presented in Figure1 and result obtained in table 2 and table3 do not signify good results on PSNR and MSE measurement front. The results obtained in Figure2 (g) reveal that with zero or medium noise level, the filter effectively removes the noise from the fingerprint image. When filter is applied to a image which has noise level too high, filter could not remove noise effectively. Overall average PSNR value obtained in table2 is showing good results but individual Gabor filter PSNR results is not up to mark.MSE value obtained in table3 is also not significant and showing good result. Though the image is further enhanced by frequency filter and directional filter, improves the performance of design to objective level. So future course of research work can be focused on improving results in front of PSNR and MSE on Gabor filter bank as it does very good orientation extraction and noise removal up to medium noise level.

Future Work

Design presented and coded in Figure1 have complexity issue as all design in frequency domain in open literature also found the same. It suffers processing speed problem because many filters are added in enhancement process. New generation of computer system have solved this issue to some extent but some other programming method can be explored to make faster processing operations. Presence of noise and other artifacts of pre-processing device, minutiae detection process can be characterized alarming. A post processing algorithm capable of identifying and cancellation of false minutiae need to be devised in future course of action. Biometrics data transmitted over network terminals are very much prone to noise, error and various forms of fraudulent attack. Encryption provides immunity over network. System immunity from various forms of errors and attack can also be thought of future course of research work as encryption itself will not full fill complete solution for this problem.

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